2L-1 Coagulation and Flocculation

Tanners Lake alum injection facility - Oakdale, MN
Source: Minnesota Stormwater Manual

Pollutant Removal Low = <30% Medium = 30-65% High = 65-100%			
	Low	Med	High
Suspended Solids			■
Nitrogen		■	■
Phosphorous		■	
Metals			■
Bacteriological			■
Hydrocarbons		■	

Description: Chemical treatment of stormwater runoff entering a wet pond by injecting liquid alum into storm sewer piping on a flow-weighted basis during rain events. Variations include aluminum sulfate, ferric chloride, chitosan, and polyacrylamide. Chemical and biological treatments are typically used as a final or polishing step in the treatment train. The process of adding an aluminum sulfate salt, otherwise known as alum, to stormwater is called alum injection. Alum injection can help meet downstream pollutant concentration loads by reducing concentrations of fine particles and soluble phosphorus. A period of detention allows the flocculated water to settle and provide effective removal of the flocculated particles. The process can also be applied to other pollutants that are attached to suspended sediment such as phosphorous and metals.

Typical Uses: Higher density residential areas, high-density ultra urban areas, industrial areas, treatment of regional detention basin discharge for additional turbidity control.

Advantages:

- Provides effective control of turbidity, phosphorous, and metals where higher levels of removal are required. Can help project meet stringent water clarity and sediment-bound pollutant removal standards
- Reduces the need for additional land purchase (in lieu of detention for sediment removal)
- Intended for areas requiring regional stormwater treatment from a piped stormwater drainage system.
- Quickly removes suspended clays and silts
- Can be used as pre-treatment to remove suspended sediments prior to infiltration.
- Suitable for cold climates

Limitations:

- High capital and operations and maintenance costs
- Complex operational requirements and ongoing operation and maintenance of the chemical addition system may be required.
- A pond or sediment collection area is necessary downstream of the treatment site for settling out the flocculants; frequent removal and disposal of chemical/sediment deposits.
- Monitoring may be required to determine the impact on downstream resources. May require NPDES permit from DNR.
- Expensive to build and operate.

Maintenance Requirements:

- Prepare stock and daily feed solutions of coagulant.
- Service chemical feed equipment daily and/or weekly.

A. General description

The process of adding aluminum sulfate salt treatment, otherwise known as alum, to stormwater is called alum injection. The process provides treatment of stormwater runoff from a piped stormwater drainage system entering a wet pond by injecting liquid alum into storm sewer lines on a flow-weighted basis during rain events. When added to runoff, liquid alum forms nontoxic precipitates of aluminum hydroxide [$Al(OH)_3$] and aluminum phosphate [$AlPO_4$], which combine with phosphorus, suspended solids and heavy metals, causing them to be deposited into the sediments of the receiving basin in a stable, inactive state. Slow mixing during the period of detention causes the fine colloidal particles to flocculate into larger particles. A period of detention allows the flocculated water to settle and provide effective removal of the flocculated particles. The process can also be applied to other pollutants that are attached to suspended sediment such as phosphorous and metals. The alum precipitate formed during coagulation of stormwater can be allowed to settle in receiving water or collected in small settling basins. Alum precipitates are stable in sediments and will not re-dissolve due to changes in redox potential or pH under conditions normally found in surface water bodies. Laboratory or field testing may be necessary to verify feasibility and to establish design, maintenance, and operational parameters, such as the optimum coagulant dose required to achieve the desired water quality goals, chemical pumping rates and pump sizes.

In a typical detention pond, suspended clays and other small particles are not well removed because they require long detention times to settle out. The addition of chemical coagulants allows the small suspended particles to group together to form a larger conglomerate particle (or flocculent) that will settle more rapidly out of the water column. Chemical and biological treatment can be a passive system of flow through a solid form of the media, but it will often require the installation of monitoring and metering devices to ensure that the coagulant solution is added at the proper dosage. Chemical treatment can also be used as a temporary or one-time use product for construction or emergency situations.

B. Pollutant removal capabilities

Alum treatment has consistently achieved a 85% to 95% reduction in total phosphorus, 90% to 95% reduction in ortho-phosphorus, 60% to 70% reduction in total nitrogen, 50% to 90% reduction in heavy metals, 95% to 99% reduction in turbidity and TSS, 60% reduction in BOD, and >99% reduction in fecal coliform bacteria compared with raw stormwater characteristics. Limited performance data of alum injection is available in Table 1. One study (Harper and Herr, 1996) found high removal rates for TSS and fecal coliform bacteria. This and another study (Carr, 1998) showed mixed results on total phosphorus and ortho-phosphorus.

Table 1: Alum injection removal rates

Study Source	TSS	Pollutant Type/Percent Removed						
		TP	Ortho-phosphorous	TN	Fecal coliform bacteria	Heavy metals	Zinc	Ammonia
Harper & Herr, 1996	95-99	85-95	90-95	60-70	99	50-90	N/A	N/A
Carr, 1998		37	42	52			41	24

The following pollutant removal rates can be used as nominal average pollutant reduction percentages for design purposes:
- Total suspended solids - 90%
- Total phosphorus - 80%
- Total nitrogen - 60%
- Fecal coliform - 90%
- Heavy metals - 75%

C. Design criteria and specifications

Alum treatment systems are fairly complex, and design details will depend on the size of the drainage area and specific site conditions. The following are general guidelines for alum treatment systems:
- Injection points should be 100 feet upstream of discharge points.
- Alum concentration is typically 10 mg/l.
- Alum treatment systems may need to control pH. A lime feed system is typically used for pH control. A more complex system would use sodium hydroxide which can be somewhat hazardous to handle.
- For new pond design, the required size is approximately 1% of the drainage basin size, as opposed to 10% to 15% of the drainage basin area for a standard detention pond.
- No volume requirement is necessary when discharging to existing lakes.

When selecting or specifying a chemical treatment method, designers should consider the following:
- What are the minimum or maximum drainage areas recommended for the device or method?
- What are the characteristics of the pollutants in the water used for testing?
- The average expected turbidity for the runoff event and the expected flow rate need to be estimated in order to establish an appropriate dosing rate.
- A pilot study using a sample of stormwater from a typical runoff event should be completed to estimate the required dosage rates and flow quantities; a bench-top test (“jar tests”) should be completed to confirm expected dosages, pH and alkalinity constraints, and final effluent turbidities.
- What are anticipated impacts from the chemical discharged into a natural water body?
- The desired detention time required for the chemical treatment agent to cause flocculation. Flocculation periods of 20 to 30 minutes, followed by 2 to 3 hours of settling, are nominal minimum requirements.
- How often must dosing rates be changed? Can an automated dosing system, paced to the flow rate be implemented?
- What are the construction costs? Does the cost include all materials, installation, and delivery?
- What are the maintenance requirements? What are the costs of the required maintenance? Is there a standard operation and maintenance plan?

Alum treatment systems generally consist of three parts, a flow-weighted dosing system that fits inside a storm sewer manhole, remotely located storage tanks that provide alum solution to the dosing mechanism, and a downstream pond that allows the alum, pollutants, and sediments to settle out (Kurz, 1998). When injected into stormwater, alum forms the harmless precipitates aluminum phosphate and aluminum hydroxide. These precipitates combine with heavy metals and phosphorus and sink into the sediment in a stable, inactive state (WEF, 1992). The collected mass of alum precipitates, pollutants, and sediments is commonly referred to as “floc.”

D. Siting and design considerations

To properly apply alum and dispose of the floc, alum injection systems need to incorporate several design features. The design needs to incorporate a dosing system, as well as sufficient chemical storage in tanks to minimize the frequency with which they need to be refilled. Dosage rates, which range from 5 to 20 mg of Al per liter (as Al+++), are determined on a flow-weighted basis during storm events. Other chemicals, such as lime, may also be added during the process to provide alkalinity and enhance pollutant settling. Lime addition will need to be controlled to avoid over-application and raising the pH too high (i.e. > 8.0).

The floc that settles in downstream basins will contain high concentrations of dissolved chemicals, (phosphorous, metals), as well as viable bacteria and viruses. In addition to the sedimentation basin or settling pond, a separate floc collection pump-out facility should be installed to reduce the chance of re-suspension and transport of floc to downstream water bodies. The facility's pumps dispose of the floc into a sanitary sewer system, a nearby upland area, or a sludge drying bed. However, pumping into a sanitary sewer system will generally require a permit. The quantity of sludge produced at a site can be as much as 0.5% to 1% of the volume of water treated.

E. Limitations

While alum shows some potential as a stormwater treatment method, it has several limitations, including:

- While the use of the alum in drinking water treatment and wastewater treatment is well established, alum injection in stormwater is an experimental practice, and little is known about its long-term performance.
- In addition to maintenance, alum injection requires ongoing operational control, unlike most other post-construction stormwater treatment practices.
- While alum injection can reduce pollutant loads, it cannot control flows or protect downstream channels from erosion.
- Chemicals added during the alum injection process may have negative effects on downstream waters.
- The precipitates from the alum increase the solids that must be disposed.

F. Maintenance considerations

Operation and maintenance for alum treatment is critical. Some typical items include:

- Routine inspection and repair of equipment, including the dosing system and pump-out facility.
- A trained operator should be on-site to adjust the dosage of alum and other chemicals, and possibly to regulate flows through the basin.
- Floc stored on-site in drying beds will need to be disposed of regularly.
- The settling basin must be dredged periodically to dispose of accumulated floc.

G. Cost considerations

Alum injection is a relatively expensive practice. Construction costs for existing alum stormwater treatment facilities in Florida have ranged from $135,000 to $400,000, depending on the watershed size and the number of outfall locations treated. Generally, alum treatment is applied to large drainage areas. In one study (Kurz, 1998) an alum treatment system was a successful stormwater retrofit for a 460 acre urbanized watershed in downtown Tampa. The capital construction costs of alum stormwater treatment systems is independent of watershed size and depends primarily on the number of outfall locations treated. Operation and maintenance costs, including routine and chemical inspections, range from $6,500 to $25,000 per year (Harper and Herr, 1996). O&M costs include chemical, power, manpower for routine inspections, equipment renewal and replacement costs.

References

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